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THE EFFECT OF WATER AND ICE ON MICROWAVE TRANSMISSION THROUGH RADOMES

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PUBLICATION REVIEW

The publication of this note does not constitute approval by the Air Force of the findings or the conclusions contained therein. It is published only for the exchange and stimulation of ideas.

FOR THE COMMANDING GENERAL:

R E Long

for RICHARD S. CARTER
Colonel, USAF
Chief, Components and Systems Laboratory
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FOREWORD

Thanks are extended by Components and Systems Laboratory to Douglas Aircraft Company of Santa Monica, California for their permission to publish the photographs and related technical information included in this technical note. Components and Systems Laboratory is also grateful to All-Weather Section, Directorate of Flight and All-Weather Testing, WADC and to the Aeronautical Icing Research Laboratory at Willow Run, Michigan for their cooperation in the experimental program now underway in the concerted effort to solve the de-icing and anti-icing of radomes. Permission to publish Photographs SM135642 and SM135644 through SM135646 and related technical data was provided by Douglas Aircraft Company.

Work relative to the development of icing and de-icing of radomes is being accomplished under RDO No. 112-12.

INTRODUCTION

Photographic evidence of the adverse effects of water films, ice accumulations, and interfering atmospheric moisture (moisture which lies between the radome and the target but not deposited on the radome) on radar microwave transmission through radomes is presented herein. The purpose of this technical note is to call attention to the seriousness of the problem and to provide visual proof and experimental evidence (Photographs SM135642, page 5; SM135644, page 6; SM135645, page 7; and SM135646, page 8) of the need for further investigation in order to arrive at basic data necessary for future radome design.

It has long been the contention of Components and Systems Laboratory that water films and ice accumulations on radome surfaces cause adverse effects on microwave transmission. Preliminary investigations were made by Components and Systems Laboratory and North American Aviation, Inc. to substantiate this theory. Concurrently, Douglas Aircraft Company of Santa Monica, California, on their own initiative, ran tests to demonstrate the validity of this theory.

To run the tests described herein, Douglas Aircraft Company used a Radar Set AN/APS-42 which was installed on various Douglas airplanes. Photographs of the radar scope under both ground and flight operation show the comparative results of interfering atmospheric moisture, water films, and ice on microwave transmission through the radome.

ANALYSIS OF RADAR SCOPE PHOTOGRAPHS

Photograph SM135644, page 6, is a presentation of radar scope pictures taken of the same target from a common location, the variable condition being the presence of a large thunderhead between the target and the test plane, as compared with clear weather operation. A comparison of Figures 1 and 2 illustrates the attenuation or loss of range caused by the presence of interfering atmospheric moisture in large amounts.

Photograph SM135642, page 5, was taken while the radome was under test on the ground. A fire hose was used to produce the 1/8-inch thick sheet of water on the surface of the radome. A comparison of the scope picture made under dry conditions with the scope picture taken when the radome had a thick surface water sheet gives evidence of a major reduction in microwave energy transmission through the radome.

Photograph SM135646, page 8, was also taken under ground test conditions. Here, a fine spray was used to wet the surface of the radome. The radar scope pictures indicate evidence of radar degradation even with a light water film present on the surface of the radome.

Finally, Photograph SM135645, page 7, was taken during flight and under moderate icing conditions on the surface of the radome. While heading towards the coast in the clear sunshine most of the ice on the left side of the radome started to melt, producing a thin film of water on this surface of the radome. These pictures serve to illustrate the relative effects of rain and ice on radar transmission. By comparison of the two pictures, it can be deduced that the presence of a water film on a radome surface produces more serious attenuation of radar transmission than that caused by moderate icing conditions.

OTHER EXPERIMENTAL PROGRAMS INITIATED

To further the knowledge of the effects of weather on microwave transmission, experimental programs relative to de-icing and anti-icing of radomes have been initiated. A program is to be conducted by the All-Weather Section, Directorate of Flight and All-Weather Testing, WADC under the technical supervision of the Components and Systems Laboratory. This program will be conducted in two phases. As one phase of the program, airborne tests will be performed under varying weather conditions such as rain, ice, and clear weather. An F-94C aircraft having a liquid spray anti-icing system will be used as the test aircraft. From these tests, data on frequency pulling, transmission efficiency, lock-on distance, and radar scope photographs will be obtained. Although boresight-error information is of great interest to this Laboratory, such information cannot be obtained readily from the airborne tests.

The second phase of the program is to be conducted at the Mt. Washington Icing Establishment, New Hampshire by the Aeronautical Icing Research Laboratory, Willow Run, Michigan. A North American thermally anti-iced radome will be used as a test bed during these tests. Data on frequency pulling, transmission efficiency, boresight shift, radar scope picture, and lock-on distance will be obtained. Static tests will also be conducted on test radomes which have been coated with oil, grease, etc.--coatings whose properties suggest that the coatings are ice or water repellant materials.

A program is being initiated to ascertain, quantitatively, the results of the early studies of the effect of rain and ice accumulations on surfaces and the effect of such accumulations on radar microwave transmission through the radome. From these quantitative results, it is expected that it will be possible to arrive at basic data necessary for future radome design.

CONCLUSIONS

The information provided by Photographs SM135642, page 5; SM135644, page 6; SM135645, page 7; and SM135646, page 8, was analyzed. The analysis indicates rather conclusively that interfering atmospheric moisture, water films, and ice accumulations all have a detrimental effect on radar microwave transmission.

It was concluded that one of the most important purposes of the flight and static test programs to be conducted must be to determine the attenuation and boresight shift caused by ice and water films on the surface of the radome, compared with the attenuation caused by interfering atmospheric moisture content and precipitation. If it is determined that the atmospheric moisture and precipitation situated between the target and the aircraft severely degrades radar microwave transmission and boresighting accuracy, as compared with that degradation caused by ice and water films on the surface of the radome, it would seem impractical to provide a system to remove these accumulations from radome surfaces. However, if interfering atmospheric moisture does not represent the major penalty then the problem to be dealt with is the removal of both ice and water accumulations from the surface of the radome.

The solution of the problem of removing ice and water accumulations from the surface of the radome may lie in a thermal system designed to vaporize the water film from the surface of the radome, in a chemical coating which will provide for the removal of water and ice accumulations on radome surfaces, or in some other system as yet unknown. In any case, the problem of ice accumulations, which are present even in clear weather after transversing an icing cloud, is a serious one as far as radar microwave transmission is concerned, and an adequate system for its prevention or removal must be provided.

Whatever the results of the flight and static tests may be, the field of radome design must concern itself with these problems because adverse weather conditions must be anticipated. Those aircraft, which are equipped with radar and which have a radome protruding into the airstream, may be heavily penalized in aircraft gun-laying, missile guidance, and search radar installations under rain and icing conditions. In some instances, such radar would be totally inoperative.

All radome designers and aircraft manufacturers are urged to carefully study the photographs presented herein and to consider the need for a system which will adequately remove ice accumulations and possibly both water and ice formations.

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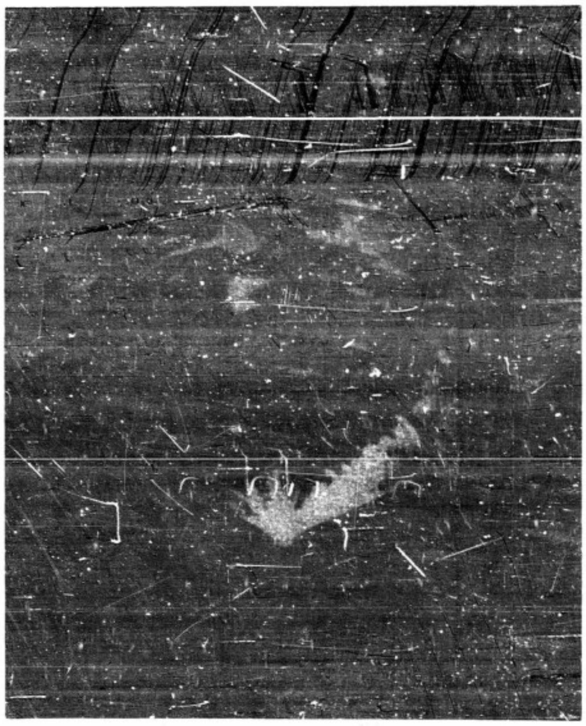
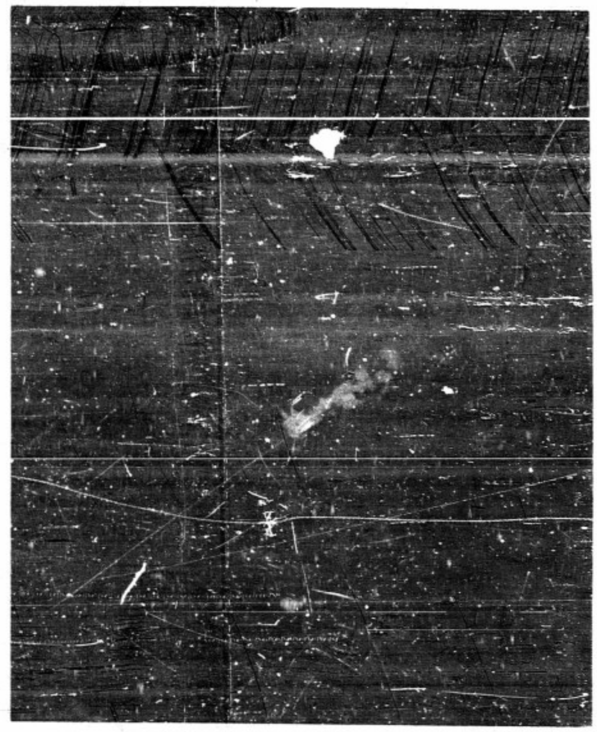


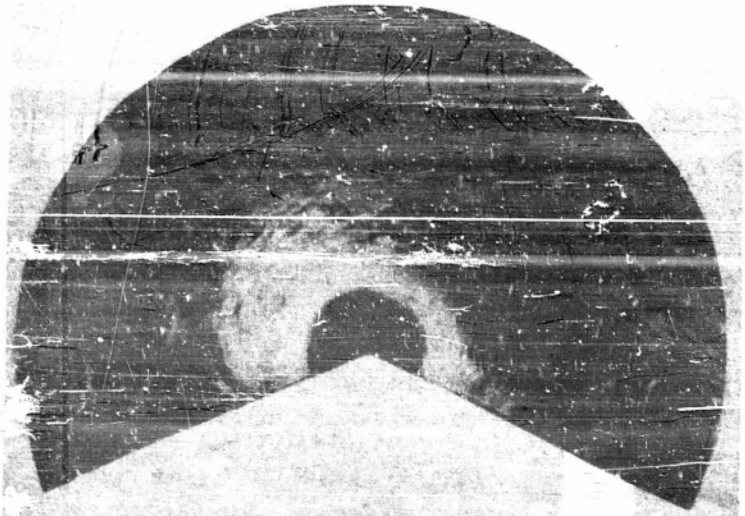
1



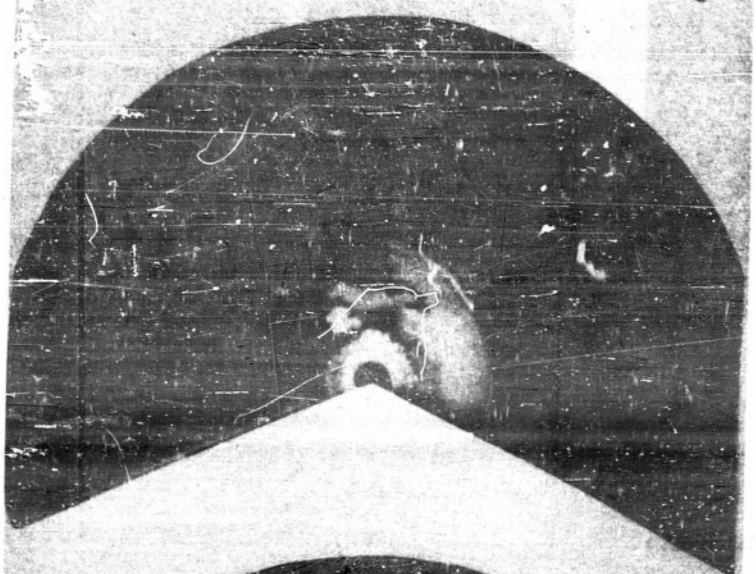
2

1. 5 mile range on flight line.

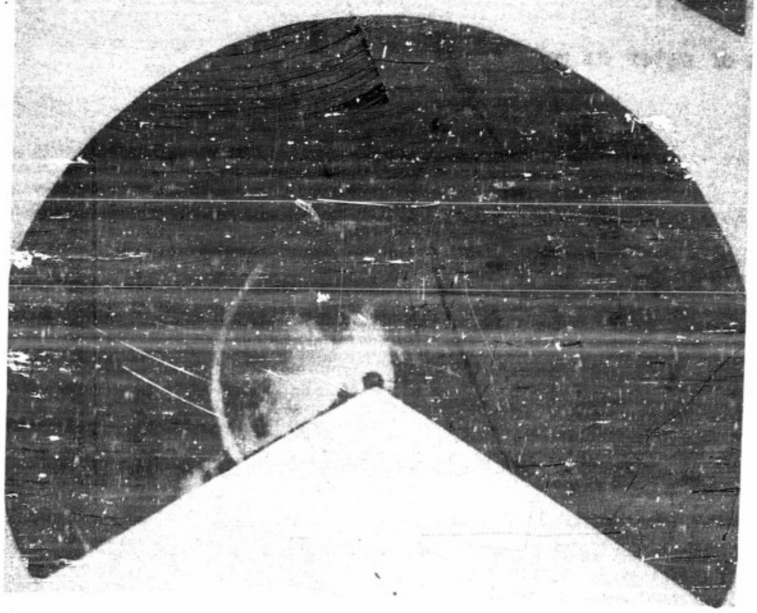
2. Same with 1/8" sheet of water on radome.



#1 was taken at 20,000 ft. 100 mile range, over Arlington, California, in CAVU weather.



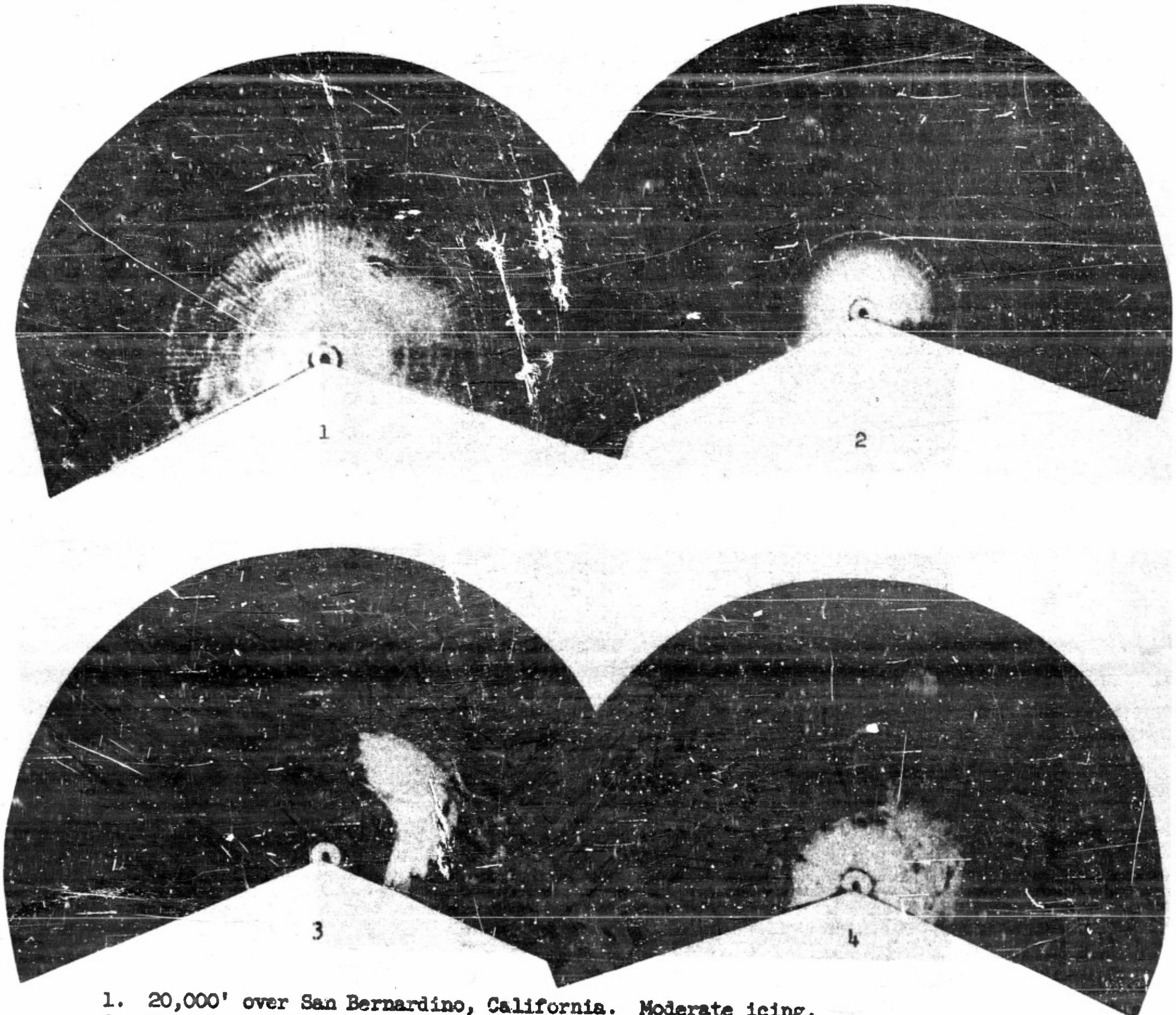
#2 is over the same location under the same conditions, except for a large thunderhead 2 miles N.E. of Arlington.



#3 is taken on the 5 mile range and pencil beam to this thunderhead.

Icing on the C-118

Range 100   Antenna on "Search"



1. 20,000' over San Bernardino, California. Moderate icing.
2. Same location. Radar practically useless due to heavy icing. Notice maximum attenuation ahead due to thicker ice on nose of radome.
3. Heading towards the coast in the clear sunshine. Most of the ice on the left of radome has started to melt, thus attenuating this side more, due to the thin water film. Tilt is 0°.
4. Same as above with tilt at -5°. Seems that more energy gets out of bottom of dome where there is little or no ice.

1

2

Picture #1 was taken on the flight line with the gain adjusted to show target 12 oclock and 2 miles.

Picture #2 shows the same except that a fine spray is being applied to the radome. The target has disappeared and the range materially reduced.